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Information Technology – Geographic Information Framework Data Content Standard

Part 2: Digital orthoimagery

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Foreword

Geographic information, also known as geospatial information, both underlies and is the subject of much of the political, economic, environmental, and security activities of the United States. In recognition of this, the United States Office of Management and Budget issued Circular A-16 (revised 2002), which established the Federal Geographic Data Committee (FGDC) as a coordinating organization.

Work on this standard started under the Geospatial One-Stop e-Government initiative. The standard was developed with the support of the member agencies and organizations of the FGDC and aids in fulfilling a primary objective of the National Spatial Data Infrastructure (NSDI), that is, creation of common geographic base data for seven critical data themes. The seven core data themes are considered framework data of critical importance to the spatial data infrastructure.

The increasing need to coordinate collection of new data, identify applicability of existing data, and exchange data at the national level led to the submission of this standard to the ANSI process to become an American National Standard. The national standard contained in this document and its parts was sponsored by Technical Committee L1, Geographic Information Systems, of the InterNational Committee for Information Technology Standards (INCITS), an ANSI-accredited standards development organization.

As the Geographic Information Framework Data Content Standard was developed using public funds, the U.S. Government will be free to publish and distribute its contents to the public, as provided through the Freedom of Information Act (FOIA), Part 5 United States Code, Section 552, as amended by Public Law No. 104-231, "Electronic Freedom of Information Act Amendments of 1996".

Introduction

The primary purpose of this part of the Geographic Information Framework Data Content Standard is to support the exchange of orthoimagery information. This part also seeks to establish a common baseline for the semantic content of orthoimagery databases for public agencies and private enterprises. It seeks to decrease the costs and simplify the exchange of orthoimagery data among local, Tribal, State, and Federal users and producers. That, in turn, discourages duplicative data collection. Benefits of adopting the part also include the long-term improvement of the geospatial orthoimagery data through the establishment of Web data services for orthoimagery data and maps within the community.

This part is intended to facilitate the interchange and use of digital orthoimagery data under the framework concept. Because of rapidly changing technologies in the geospatial sciences, this part of the Geographic Information Framework Data Content Standard, Part 2: Digital Orthoimagery covers a range of specification issues, many in general terms. This part is based on an approved FGDC standard, Content Standards for Digital Orthoimagery, FGDC-STD-008-1999. The Geographic Information Framework Data Content Standard, Part 2: Digital Orthoimagery has been developed for adoption through the INCITS Technical Committee L1 on Geographic Information Systems, as an American National Standard.

Framework Data Content Standard – Digital orthoimagery

1 Scope, purpose, and application

1.1 Scope

Digital orthoimagery is one of the basic digital geospatial data framework themes as envisioned by the Federal Geographic Data Committee. This part of the Geographic Information Framework Data Content Standard specifies data content and logical structure for the description and interchange of framework digital orthoimagery. To a certain extent, it also provides guidelines for the acquisition and processing of imagery (leading toward the generation of digital orthoimagery), and specifies the documentation of those acquisition and processing steps. The primary focus of this part is on images sensed in the visible to near infrared portion of the electromagnetic spectrum. However, images captured from other portions of the electromagnetic spectrum are not precluded.

1.2 Purpose

It is the intent of this part of the Framework Data Content Standard to set a common baseline that will ensure the widest utility of digital orthoimagery for the user and producer communities through enhanced data sharing and the reduction of redundant data production. The framework will provide a base on which to collect, register, and integrate digital geospatial information accurately.

This part is intended to facilitate the interchange and use of digital orthoimagery data under the framework concept. Because of rapidly changing technologies in the geospatial sciences, this part covers a range of specification issues, many in general terms. This part stresses complete and accurate reporting of information relating to quality control and standards employed in testing orthoimagery data.

1.3 Application

The Digital Orthoimagery part applies to NSDI framework orthoimagery data produced or disseminated by or for the Federal government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure, Federal agencies collecting or producing geospatial data, either directly or indirectly (for example, through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the Federal Geographic Data Committee (FGDC) process.

Each thematic part of the Framework Data Content Standard includes a data dictionary based on the conceptual schema presented in that part. To conform to this standard, a thematic dataset shall satisfy the requirements of the data dictionary for that theme. It shall include a value for each mandatory element, and a value for each conditional element for which the condition is true. It may contain values for any optional element. The data type of each value shall be that specified for the element in the data dictionary and the value shall lie within the domain specified for the element.

2 Normative references

Annex A lists normative references to standards that are applicable to this part of the Framework Data Content Standard. Informative references are listed in Annex F. Annex A of the Base Document (Part 0) lists normative references applicable to two or more parts of the standard. Annex D of the Base Document lists informative references applicable to two or more of the parts.

3 Standards development

This document is based on an approved FGDC standard, Content Standards for Digital Orthoimagery, FGDC-STD-008-1999, developed initially by the Subcommittee on Base Cartographic Data of the FGDC. The Standards Reference Model, developed by the Standards

Working Group of the FGDC, provides guidance to FGDC subcommittees for the standards development process. The Geographic Information Framework Data Content Standard, Part 2: Digital Orthoimagery has been developed for adoption through the INCITS Technical Committee L1 on Geographic Information Systems, as an American National Standard.

4 Maintenance authority

4.1 Level of responsibility

The FGDC is the responsible organization for coordinating work on all parts of the Geographic Information Framework Data Content Standard. The U.S. Department of the Interior, United States Geological Survey, National Geospatial Programs Office, working with the FGDC, is directly responsible for development and maintenance of the Geographic Information Framework Data Content Standard, Part 2: Digital Orthoimagery.

The FGDC shall be the sole organization responsible for direct coordination with the InterNational Committee for Information Technology Standards (INCITS) concerning any maintenance or any other requirements mandated by INCITS or ANSI.

4.2 Contact information

Address questions concerning this part of the standard to:

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12201 Sunrise Valley Drive
Reston, VA, 20192

5 Terms and definitions

Definitions applicable to the Digital Orthoimagery part are listed below. More general terms can be found in the Base Document (Part 0).

5.1
aerotriangulation

process of using aerial **imagery** or the extension of horizontal and/or vertical control whereby the measurements of angles and/or distances on overlapping **imagery** are related into a spatial solution using the perspective principles of the **imagery** [American Society of Photogrammetry, 1980]

5.2
airborne global positioning system
AGPS

equipment used to provide initial approximations of exterior orientation, which defines the position and orientation associated with an image as they existed during image capture [Leica Geosystems GIS & Mapping, LLC]

5.3
aliasing

effect on a view of a raster file in which smooth curves and other lines become jagged because the resolution of the graphics device or file is not high enough to represent a smooth curve

5.4
band

range of wavelengths within the electromagnetic spectrum

EXAMPLE The near infrared band.

5.5
band interleaved

ordered mixing of data from one or more **bands** with corresponding data from other **bands** for the purpose of forming a single image file

NOTE Images ordered band interleaved by line store values for each band by line sequentially prior to going to the next line and often carry the extension .bil. Images ordered band interleaved by pixels store pixel values for each band before going to the next pixel. They often carry the file extension .bip.

5.6
band sequential

sequence of one image **band** followed by another image **band**

NOTE A band sequential file can be formed by appending bands in sequence within a single file.

5.7
bilinear interpolation

mathematical computation for an unknown value based on linear **interpolation** along two axes

NOTE The axes are derived using a coordinate transformation algorithm to locate the quadrilateral of the four nearest profile points surrounding the unknown point. The interpolation computes the unknown value based on the average, by use of weights and distances, of the four nearest known values.

5.8
color infrared
false color

method for viewing or designating images sensed in the portion of the electro-magnetic spectrum generally from about 0.5 to 1.0 micrometers

5.9
cubic convolution

mathematical sampling technique for the interpolation of an unknown value based on a third degree polynomial equation using surrounding known values

NOTE The image is interpolated from the brightness values of the 16 nearest pixels of the corrected pixel.

5.10
digital image

image stored in binary form and divided into a matrix of **pixels**, each consisting of one or more bits of information that represent either the brightness, or brightness and color, of the image at that point

5.11

digital number
brightness number

relative reflectance or emittance of an object in a **digital image**

NOTE Digital number is generally referred to as DN.

5.12
digital orthoimage

georeferenced **digital image** or other remotely-sensed data, in which **displacement** of objects in the image due to sensor distortions and orientation, as well as terrain relief, have been removed

5.13
displacement

shift in the position of an image on an image resulting from tilt, scale change, and relief of the area imaged [EM 1110-1-1000]

5.14
georegistration

alignment of one image to another image of the same area by placing any two **pixels** at the same location in both images “in register” resulting in samples at the same point on the Earth

5.15
ground sample distance
ground sample interval
ground resolution
ground pixel resolution

distance on the Earth of the smallest discrete unit of measurement within an orthoimage in the x and y components

5.16
horizontal accuracy

accuracy of horizontal position

5.17
horizontal datum

datum to which horizontal locations of points are referenced

5.18
imagery

visible representation of objects and/or phenomena as sensed or detected by cameras, infrared and multispectral scanners, radar, and photometers [EM 1110-1-1000]

5.19
inertial measurement unit

instrument that records the pitch, roll, and heading of a remote sensing platform

5.20
mosaic

assemblage of overlapping or adjacent photographs or **digital images** whose edges have been matched to form a continuous pictorial representation of a portion of the Earth’s surface

5.21

natural color

pertaining to the electro-magnetic spectrum, 0.4 to 0.7 micrometers, that measures blue, green, and red reflectance

5.22
orthorectification

process of removing geometric errors inherent within photography and **imagery** caused by relief **displacement**, lens distortion, and the like [Leica Geosystems GIS & mapping, LLC]

5.23
panchromatic

pertaining to monospectral **imagery** that records the intensity of reflected or emitted radiation in the visible spectrum, 0.4 to 0.7 micrometers

5.24
pan-sharpening

fusing of high-**resolution panchromatic** imagery with lower-**resolution**, multispectral imagery to create a high **resolution** multispectral image

5.25
pixel
picture element

smallest discrete unit of information found in an image

NOTE A picture element may have an associated physical metric, size, or interval.

5.26
radiometric resolution

sensitivity in discriminating between intensity levels

NOTE Radiometric resolution is inversely related to the number of digital levels used to express the data collected by the sensor. The number of levels is normally expressed as the number of binary digits needed to store the value of the maximum level, for example a radiometric resolution of 1 bit would be 2 levels, 2 bit would be 4 levels and 8 bit would be 256 levels. The number of levels is often referred to as the digital number, or DN value. [Association of Geographic information, 1996]

5.27
resample

derive values for **pixels** by interpolation of surrounding **pixel** values

5.28
resolution

ability of a sensor to render a sharply defined image

NOTE Also see, radiometric, spectral, and spatial resolution.

5.29
spatial resolution

minimum area on the ground that an imaging system, such as a satellite sensor, can distinguish

5.30
spectral resolution

sensitivity in discriminating between wavelengths

NOTE Spectral resolution measures the total wavelength range of a band in which radiation is measured to produce an image.

5.31
survey

act or operation of making measurements for determining the relative positions of points on, above, or beneath the Earth's surface [American Society of Photogrammetry, 1980]

5.32
vertical accuracy

accuracy of elevation

5.33
void areas

areas in an elevation coverage with no data

6 Symbols, abbreviated terms, and notations

The following symbols, abbreviations, and notations are applicable to this part of the standard. More symbols, abbreviations, and notations applicable to multiple parts are listed in the Base Document (Part 0).

AGPS – Airborne Global Positioning System

BIL – Band Interleaved by Line

BIP – Band Interleaved by Pixel

BSQ – Band Sequential

CIR – Color Infrared

DN – Digital Number

DOQQ – Digital Orthophoto Quarter Quadrangle

GSD – Ground Sample Distance

IMU – Inertial Measurement Unit

INS – Inertial Navigation System

IPI – Image Processing and Interchange

MODIS – Moderate Resolution Imaging Spectroradiometer

SDTS – Spatial Data Transfer Standard

SPCS – State Plane Coordinate System

SPOT – Satellite Pour d'Observation de la Terre

TM – Thematic Mapper

WGS84 – World Geodetic System of 1984

7 Data description

Digital orthoimages are georeferenced images of the Earth's surface, collected by a sensor, from which image object displacement has been removed by correcting for sensor distortions and orientation, and for terrain relief. Digital orthoimages encode the optical intensity of sensed radiation in one or more bands of the electromagnetic spectrum as discrete values in an array of georeferenced pixels that model the scene observed. Digital orthoimages have the geometric characteristics of a map. Digital orthoimages are captured from a wide variety of sources and are available in a number of formats, spatial resolutions, and areas of coverage. Many geographic features, including some in other framework data themes, can be interpreted and compiled from an orthoimage.

8 Requirements

8.1 Digital orthoimagery structure

Framework digital orthoimagery shall consist of images, each of which consists of a two-dimensional, rectangular array of pixels. The ground area covered by each pixel, called ground resolution cells, determines the resolution of each pixel. The pixels shall be arranged in horizontal rows (lines) and vertical columns (samples). The order of the rows shall be from top to bottom; the order of columns shall be from left to right. The uppermost left-hand pixel shall be designated pixel (0,0). Images describing more than 1 band of electromagnetic radiation (natural color, color infrared, multi-band) shall be structured in one of three orders: band interleaved by line (BIL), band interleaved by pixel (BIP), or band sequential (BSQ). The image shall have equal line (row) and column lengths, resulting in a rectangular image. This may be accomplished by padding with over-edge image or non-image pixels, that have a digital number (DN) equal to zero (black or no reflectance), to an edge defined by the extremes of the image. The bounding coordinates of the image shall be documented in accordance with the FGDC Content Standard for Digital Geospatial Metadata. For images that contain over-edge coverage or are padded with non-image pixels, descriptions of both the specific area of interest and any over-edge coverage shall be documented by the metadata. When over-edge information in the image exists, the producer is obliged to describe the image quadrangle in metadata.

NOTE Some digital orthoimagery quadrangles include over-edge imagery beyond the boundaries of the area of interest. This part recognizes that annotations may be included in an over-edge image. These images are generally created using color lookup tables that provide for a transparent pixel value to accommodate the portrayal of the over-edge information; otherwise this part limits the orthoimage to the significant pixel values of the image.

NOTE Photo enlargements, simply rectified and rubber sheeted images are not orthoimages and do not comply with the basic procedures involved in photogrammetry that produce accurate orthoimages.

8.2 Resolution

When referring to orthoimagery, three different definitions of resolution are important: spatial, spectral, and radiometric.

8.2.1 Spatial resolution

Spatial resolution is the smallest unit which is detected by a sensor [Falkner and Morgan, 2002, p.12]. Often expressed as pixel resolution or ground sample distance (GSD), it defines the area of the ground represented in each pixel in X and Y components. For the purpose of this part, framework digital orthoimages shall have a GSD of 2 meters or finer. Images may be resampled to create coarser resolution images than the original raster data. Subsampling of images may be applied only within the limits defined by the Nyquist theorem [Pratt, 1978]. Images of higher resolution can be used to create orthoimages of less resolution but the reverse is not acceptable.

NOTE The Nyquist frequency limits subsampling to a maximum of two times (2X) to avoid undesirable aliasing.

8.2.2 Spectral resolution

Spectral resolution describes a sensor’s sensitivity to a particular wavelength band or bands. For the purpose of this part, the focus for framework orthoimage will be on images sensed in the visible to near infrared portion of the electromagnetic spectrum, 0.4 to1.0 micrometers. However, this does not preclude images captured from other bands.

8.2.3 Radiometric resolution

Radiometric resolution is the sensitivity of a detector to measure radiant flux that is reflected or emitted from a ground object [Falkner and Morgan, 2002, p.12]. Relative radiance from the ground resolution cells shall be described by numerical representations (digital numbers (DNs) or brightness values) of reflected radiance amplitudes. The cell value for a single band shall be recorded as a series of binary digits or bits, with the number of bits per cell determining the radiometric resolution of the image. Where Q is a finite number of bits, the number of discrete DNs shall be given, as follows:

NDN = 2Q

The DN can be any integer in the range, as follows:

DNrange = [0, 2Q-1]

The radiance values for black and white (gray scale) image data are represented in a single band as 8 to 12-bit data and the radiance values for color images are represented by three bands of 8 to 12 bits of binary data per band.

EXAMPLE SPOT and TM are both 8 bits per pixel, AVHRR is 10 bits and MODIS is 12 bits per pixel.

NOTE Brightness values of most digital orthoimages created are commonly represented as 8-bit binary numbers with a range of values from zero, (black, no reflectance) to 255 (white, full reflectance).

8.3 Areal extent

This part places no constraints on the geographic extent of an orthoimage. Areal extent of quadrilateral orthoimagery may be adjusted as appropriate for the type of sensor and sensor platform, height, requirements of the user, and so on.

8.4 Coordinate systems and reference datums

8.4.1 Coordinate systems

A common method for referencing coordinate positions on the Earth is essential for integrating geospatial data. While it is desirable that framework data be described by longitude and latitude coordinates, orthoimagery is more often represented in a grid coordinate system, such as Universal Transverse Mercator (UTM) or State Plane Coordinate Systems (SPCS).

8.4.2 Reference datums

The North American Datum of 1983 (NAD83) or World Geodetic System 1984 (WGS84) datum shall be used as the horizontal datum for framework digital orthoimagery.

8.4.3 Georegistration

All orthoimages shall be georeferenced to reflect their correct locations, both horizontally and vertically. Georegistration will be described by a 4-tuple in the metadata which will establish the geographical position of the first pixel in the first row of the image [pixel (0,0)]. The metadata will reflect the row # = 0, column # = 0, and georeference values in X and Y for the documented datum and horizontal coordinate system. Under this part, georegistration (spatial coordinates) refers to the center of the pixel. This establishes the georegistration at one point in the orthoimage. Since row and column offsets are both constant and supplied by the metadata, (XY_pixel resolution), all other points can be georegistered. Additional 4-tuples may be provided for additional georegistration.

NOTE Photo enlargements, simply rectified and rubber sheeted images are not orthoimages and do not comply with the basic procedures involved in photogrammetry that produce accurate orthoimages.

8.5 Accuracy requirements

This part specifies that map accuracy shall be determined by comparing the mapped location of selected well defined points to their "true" location, as determined by a more accurate, independent field survey. Accuracy of new or revised spatial data shall be reported according to the National Standard for Spatial Data Accuracy (NSSDA) [FGDC-STD-007.3-1998]. Accuracy of existing or legacy spatial data and maps may be reported, as specified, according to the NSSDA or the accuracy standard by which they were evaluated.

Framework digital orthoimagery accuracy shall employ the NSSDA, which implements a statistical and testing methodology for estimating the positional accuracy of points in digital geospatial data, with respect to georeferenced ground positions of higher accuracy. This reporting methodology provides a common language for reporting positional accuracy so that users can evaluate datasets for fitness of use for their applications. The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product. The NSSDA does not define threshold accuracy values. Users are encouraged to establish thresholds for their product specifications and applications and for contracting purposes. Data producers may elect to use accuracy thresholds in standards such as the National Map Accuracy Standards of 1947 [U.S. Bureau of the Budget, 1947] or Accuracy Standards for Large-Scale Maps [American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990] if they decide that these values are applicable to their digital geospatial data accuracy requirements. However, accuracy of new or revised data products will be reported according to the NSSDA. Data producers shall ensure that all critical components have known accuracies suitable for the construction of orthoimagery, and that those accuracies are reported in the metadata. Producers of digital orthoimagery must report the horizontal positional accuracy of data.

8.5.1 Tested orthoimages RMSE

Per NSSDA, report accuracy at the 95% confidence level for data tested for both horizontal and vertical accuracy as:

Tested ____ (meters, feet) horizontal accuracy at 95% confidence level
____ (meters, feet) vertical accuracy at 95% confidence level

8.5.2 Untested orthoimages RMSE

Per NSSDA, report accuracy at the 95% confidence level for data produced according to procedures that have been demonstrated to produce data with particular horizontal and vertical accuracy values as:

Compiled to meet ____ (meters, feet) horizontal accuracy at 95% confidence level
____ (meters, feet) vertical accuracy at 95% confidence level

8.5.3 Horizontal positional accuracy narrative

Enter the text “National Standard for Spatial Data Accuracy” for these metadata elements, as appropriate to dataset spatial characteristics.

8.5.4 Horizontal positional accuracy reporting

Regardless of whether the data was tested by a independent source of higher accuracy or evaluated for accuracy by alternative means, provide a complete description on how the values were determined in metadata, as appropriate to dataset spatial characteristics.

8.6 Production components

The following section describes requirements for the primary production components of digital orthoimages: image sources, elevation data, control, and camera or sensor calibration data. It follows then that all orthoimagery discussed will be created through a true displacement rectification process. Georeferenced or “rubber-sheeted” images, therefore, are not acceptable as true orthoimages.

8.6.1 Image sources

Source for digital orthoimages may be from any remote sensing device capable of producing images with resolutions 2-meters or finer. Remote sensing devices may be photographic or electronic, airborne or satellite.

8.6.1.1 Aerial camera images

Continuous tone images in the visible light portion of the electromagnetic spectrum from aerial cameras are the primary source currently used to produce digital orthoimages. Sensor types for orthoimages compliant with this part shall be confined to black and white (panchromatic), color infrared (CIR), and natural color. Black and white orthoimages may be generated from CIR and natural color source.

8.6.1.2 Aerial photo image scanning

A digital image may be created from an analog photographic image utilizing a high-resolution scanner. The intent of the scanning process is to capture the same level of detail in the digital image as is found on the film. The combination of the scanner optical resolution setting and the scale of the source imagery will determine the ground resolution distance that can be attained from the digital image following orthocorrection. The optical resolution of the scanning process is typically measured in either micrometers or dots-per-inch and should as closely as possible match the intended ground sample distance (GSD) without excessive resampling. Resampling from a higher resolution to create a lower resolution image is acceptable.

8.6.1.3 Digital images

Images from airborne and satellite platforms, utilizing digital cameras or scanners, are increasingly more common sources used in the production of digital orthoimages. For the purposes of framework orthoimagery they include images from electro-optical, near infrared, and multi-spectral operating in the visible to near (reflected) infrared wavelengths, 0.4 to 1.0 micrometers. This document does not discuss the details and specifications of digital cameras or satellite remote sensors. Nor does it debate the advantages or disadvantages of using one image acquisition system over another.

8.6.2 Elevation data

Elevation data used to correct displacement shall be sufficiently accurate to ensure the image meets user defined requirements for the intended accuracy: the appropriate point density, point spacing, and area coverage in order to meet the accuracy requirements and scale of the orthoimage, and to reliably describe the terrain.

Note For more information on elevation data refer to Geographic Information Framework Data Content Standard, Part 3: Elevation.

8.6.3 Calibration data

With the exception of documenting the appropriate source metadata, camera or imaging instrument calibration parameters requirements for production purposes are not covered by this part.

Note Information on analog camera calibration can be found in the USGS publication, Aerial Camera Specifications (revised January 2003).

8.6.4 Control data

Control point locations are required when creating digital orthoimagery. Without control information, rigorous orthorectification is not possible. For orthorectification, control must have known X, Y, and Z-coordinate values. The process of orthorectifying the image must use a 3-dimensional (3D) space resection algorithm. Images processed via simple rectification or rubbersheeting are not considered true orthoimages: they are not true orthogonal images from which accurate measurements may be ascertained. The accuracy of the control determines the initial accuracy of the orthoimage. Control must be used to provide the 3D foundation during the orthorectification process and can be acquired from a variety of sources.

NOTE More detailed information is contained in Annex E.

9 Image rectification and restoration

Image rectification and restoration are processes for correcting distortions and degradations that result from image acquisition or production. Digital orthoimagery is processed in a number of ways, and different orthoimagery production systems have unique characteristics. However, all accept raw (or unprocessed) imagery that contain some degree of error in geometry (geometric distortion) and in the measured brightness values of the pixels (radiometric distortion). This part specifies rectification or restoration procedures only in context of geometric and radiometric corrections.

9.1 Geometric correction

All systematic and random errors shall be removed to the extent required to meet orthoimagery accuracy requirements as defined by the intended user. Nearest neighbor, bilinear interpolation, and cubic convolution resampling algorithms are common methods used to transform image values to fit map geometry. Nearest neighbor resampling is not recommended for the large-scale framework because of the disjointed appearance in the output due to spatial offsets as great as one-half pixel. Images transformed using bilinear interpolations are generally acceptable. A precise resampling method such as cubic convolution is recommended.

Note Geometric corrections are performed to match raw image data to map geometry. Distortions can be classified as either systematic (predictable errors that follow some definite mathematical or physical law or pattern associated with particular processes and instruments) or random (errors that are wholly due to chance and do not recur). Most of the distortions associated with orthoimagery are random. Terrain relief, random variation in platform position, and faulty elevation data are the sources of nonsystematic distortion, or random errors. These random errors can be detected by comparing identifiable points on an image to their known ground coordinates.

9.1.1 Image smear

When image smears occur, efforts shall be made to correct them or to identify them as anomalies. Where feasible, areas of image smear may spatially be defined as polygons, linked to documentation in lineage metadata.

Note Occasionally, because of spikes in the elevation data or excessive topographic relief, an anomaly or artifact best described as an "image smear" may appear on a rectified image. Basically, the steepness of the terrain is such that some ground image is effectively hidden from view (for example, on the backside of the mountain or the sides of a steep cliff). This can be especially prominent near the edge of images from large-scale aerial photography (generally, incidence of the anomaly decreases as the altitude of the sensor platform increases). When that portion of the scanned raster image is adjusted to its conjugate area on the elevation model, the void area in the image is assigned brightness values via an interpolation algorithm that uses the visible image surrounding the void. This sometimes results in a "smeared" or "stretched" area on the image.

9.1.2 Other elevation – related geometric distortions

Double or missing features in the image may be indications of a poor elevation model or unsuitable control. Such distortions may render the image unusable. Producers should recheck the source elevation or control to establish if the distortion is systematic or not; if the distortion is systematic, a better elevation model and (or) control should be used. Non-systematic distortions need to be reviewed on a case-by-case basis and if deemed acceptable by the producer and customer, identified and recorded in the metadata by the producer.

NOTE Linear features (such as highways and bridges) may require special treatment to maintain their alignment, form, and integrity.

9.2 Radiometric correction

Image brightness values may deviate from the brightness values of the original imagery, due to image value interpolation during the scanning, rectification, and post-processing procedures and it is common practice to perform some radiometric enhancements and corrections (for example, contrast stretching, analog dodging, noise filtering, destriping, edge matching) to images prior to release of the data. However, data producers are cautioned to minimize the amount of radiometric correction applied to an image. Data producers shall use processing techniques that minimize data loss from the time the information was captured until its release to the users.

9.3 Data completeness

Visual verification shall be performed for image completeness, to ensure that, whenever possible, no gaps exist in the image area.

9.4 Cloud cover

Any cloud cover or cloud shadows which obscure image features may render the image unusable. However, for some areas of an image (for example, over broad bodies of water) cloud cover obstruction may be deemed acceptable to some users. Therefore, some users may find images containing varying percentages of cloud cover or cloud shadow to be acceptable.

10 Image mosaicking

Single orthoimages are commonly created through the mosaicking of multiple images and many producers go through extensive image processing steps to attain a “seamless” appearance. This document will not discuss mosaic procedures nor will it prescribe the degree of quality for the appearance of mosaicked orthoimages. However, all the images that comprise the source of a mosaicked image shall be documented in the metadata field.

11 Data transfer formats

Data transfer formats for digital orthoimagery are not specified in this part. Data producers are encouraged to employ ISO and ANSI standards for information exchange. In all cases, producers shall provide detailed descriptions of the format.

12 Metadata

The FGDC emphasizes the importance of good metadata to support the exchange and use of geospatial data: providing quality information will allow users to match data to their needs. Well-crafted metadata facilitates the search and collection process while alleviating some of the burden on the user to assess quality and applicability of data. The more metadata there is for a product, the more it can support the user’s determination of its reliability, quality, and accuracy. Metadata is intended to be of value to the producer as well as to the user.

The FGDC Content Standard for Digital Geospatial Metadata [FGDC-STD-001-1998] with all FGDC-approved profiles of and extensions to it, in conjunction with ISO 19115, are the source for terminology and definitions relating to metadata. Executive Order 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure, requires all Federal agencies to use FGDC-STD-001-1998 to document data that they produce beginning in 1995.

Annex A
(normative)
Normative references

This annex lists normative standards that support only this part of the Framework Data Content Standard. Annex A of the Base Document (Part 0) lists normative references applicable to two or more parts of the standard.

FGDC-STD-007.3-1998, Geospatial positioning accuracy standards, Part 3, National standard for spatial data accuracy, http://www.fgdc.gov/standards/status/sub1_3.html, accessed January 2006

Annex B
(normative)
Orthoimagery UML model

B.1 Orthoimagery schema

B.1.1 Classes of the schema

This orthoimagery schema specified in this part (Figure B.1) includes two classes: FrameworkOrthoimage, which is a realization of three types specified in ISO 19123, and OrthoimageryCollection.

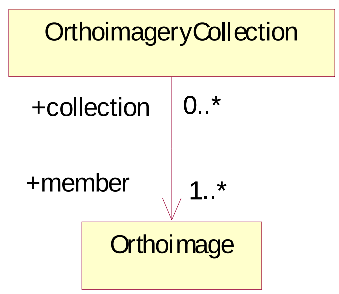

Figure B.1 – Framework orthoimagery classes

B.1.2 Orthoimage

B.1.2.1 Introduction

The class FrameworkOrthoimage (Figure B.2) realizes three types specified in ISO 19123: CV_ContinuousQuadrilateralGridCoverage, CV_GridValuesMatrix, and CV_RectifiedGrid. It implements 13 attributes specified for those types in ISO 19123, as well as one attribute and one association specified in this part. Its attributes use classes specified in ISO standards as data types.

B.1.2.2 Attribute: domainExtent

The attribute *domainExtent* shall describe the extent of the domain of the orthoimagery coverage. It uses the data type EX_Extent specified in ISO 19115. EX_Extent has several subtypes including EX_GeographicBoundingBox, EX_BoundingPolygon, EX_GeographicDescription, EX_TemporalExtent, EX_SpatioTemporalExtent, and EX_VerticalExtent. This part requires that the attribute be populated with a value for at least one of these subtypes.

B.1.2.3 Attribute: rangeType

The attribute *rangeType* shall provide a description of the attributes in the range of the coverage. The class RecordType (B.1.10) is specified in ISO/TS 19103. An instance of RecordType consists of a set of keyword:value pairs in which the keyword is an attribute name and the value is the data type of the attribute.

B.1.2.4 Attribute: interpolationType

The attribute *interpolationType* shall identify the interpolation method recommended for evaluating the coverage. The code list CV_InterpolationMethod is specified in ISO 19123.

B.1.2.5 Attribute: commonPointRule

The attribute *commonPointRule* shall identify a rule to be followed in evaluating a coverage if the position at which evaluation is to be done falls within or on the boundary between two or more domain objects. In the case of a grid coverage, it applies only if the position falls on a grid line. The code list CV-CommonPointRule is specified in ISO 19123.

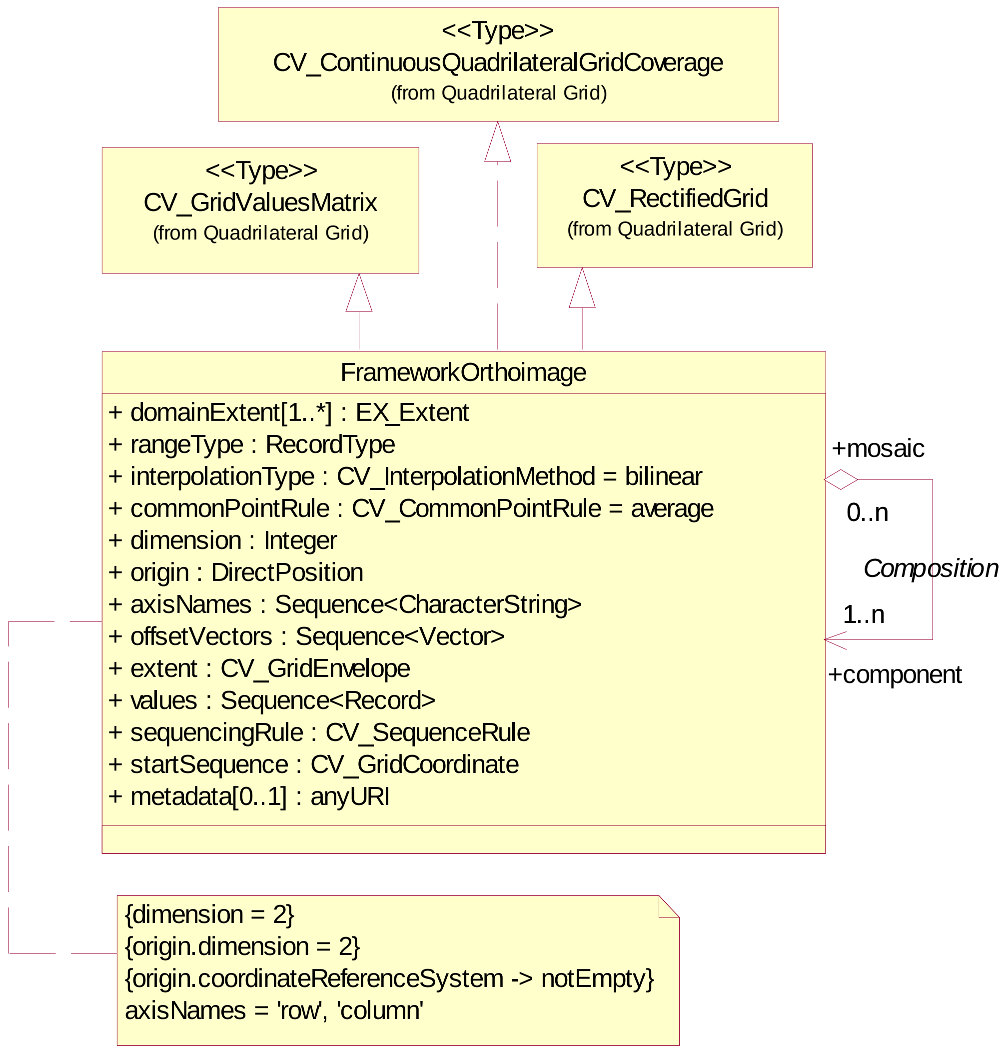

Figure B.2 – FrameworkOrthoimage

B.1.2.6 Attribute: dimension

The attribute *dimension* shall identify the dimension of the grid. In the case of orthoimagery, the grid dimension is always 2 as indicated by the constraint {dimension = 2}.

B.1.2.7 Attribute: origin

The attribute *origin* shall identify the position of the origin of the grid coordinate system with respect to an external coordinate reference system. The data type DirectPosition (B.1.7) is specified in ISO 19107. The constraint {origin.dimension = 2} indicates that the DirectPosition shall be described by a 2D coordinateDirectPosition that has an optional association to the class SC_CRS (B.1.8) specified in ISO 19111. That association is mandatory for this part, as indicated by the constraint: {origin.coordinateReferenceSystem -> notEmpty}.

This part also specifies that the external coordinate reference system shall use either the North American Datum of 1983 (NAD83) or the datum defined for the World Geodetic System of 1984 (WGS84).

B.1.2.8 Attribute: axisNames

The attribute *axisNames* shall provide a list of the names of the grid axes. The length of the list equals the value of the attribute *dimension*. This part requires the axis names to be "row" and "column" as indicated by the constraint {axisNames = "row", "column"}.

B.1.2.9 Attribute: offsetVectors

The attribute *offsetVectors* shall describe the orientation of the grid axes with respect to the external coordinate reference system as well as the spacing between grid lines. Its value is a Sequence of Vectors. The data type Vector (0) is specified in ISO/TS 19103. The length of the sequence shall equal the value of the attribute *dimension*. ISO 19123 specifies that the ordering of the sequence of *offsetVectors* shall be the same as the ordering of the sequence of *axisNames*.

B.1.2.10 Attribute: extent

The attribute *extent* shall identify the set of grid points for which attribute values are provided. The data type CV_GridEnvelope (B.1.5) is specified in ISO 19123.

B.1.2.11 Attribute: values

The attribute *values* shall provide a sequence containing all of the values associated with grid points within the extent of the coverage. Each record in the sequence shall contain the list of values for a single grid point. The data type Record is specified in ISO 19103. For this attribute, each Record shall conform to the RecordType (B.1.10) provided as the value for FrameworkOrthoimage.rangeType.

B.1.2.12 Attribute: startSequence

The attribute *startSequence* shall identify the grid coordinates of the point associated with the first record in the sequence of *values*. The data type CV_GridCoordinate (B.1.4) is specified in ISO 19123.

B.1.2.13 Attribute: sequencingRule

The attribute *sequencingRule* shall identify the rule to be followed in assigning records from the sequence of *values* to individual grid points. The data type CV_SequenceRule (B.1.6) is specified in ISO 19123.

B.1.2.14 Attribute: metadata

The attribute *metadata* shall provide a link to metadata about the FrameworkOrthoimage.

B.1.2.15 Association: Composition

The optional association Composition may link an instance of FrameworkOrthoimage to other instances in two ways. In the role of *mosaic*, an instance of FrameworkOrthoimage is characterized as an aggregate of one or more other instances of FrameworkOrthoimage. In the role of *component*, an instance of FrameworkOrthoimage is characterized as a member of one or more *mosaics*.

B.1.3 OrthoimageryCollection

B.1.3.1 Introduction

The class OrthoimageryCollection represents a set of FrameworkOrthoimages that are transferred as a set.

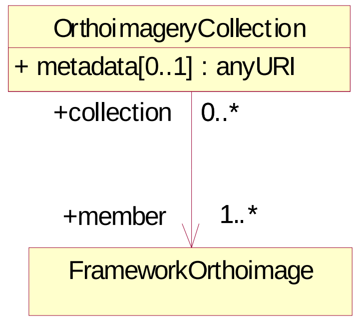

Figure B.3 – OrthoimageryCollection

B.1.3.2 Attribute : metadata

The attribute *metadata* shall provide a link to metadata about the OrthoimageryCollection.

B.1.3.3 Associated role name: member

The role name *member* identifies that FrameworkOrthoimage belongs to the OrthoimageryCollection.

B.1.4 CV_GridEnvelope

B.1.4.1 Introduction

The data type class CV_GridEnvelope (Figure B.4) has two attributes.

B.1.4.2 Attribute: low

The attribute *low* takes as its value an instance of CV_GridCoordinate that contains the minimum coordinate of the grid envelope with respect to each axis of the grid.

B.1.4.3 Attribute: high

The attribute *high* takes as its value an instance of CV_GridCoordinate that contains the maximum coordinate of the grid envelope with respect to each axis of the grid.

B.1.5 CV_GridCoordinate

B.1.5.1 Introduction

The data type class CV_GridCoordinate (Figure B.4) has a single attribute.

B.1.5.2 Attribute: coordValues

The attribute *coordValues* contains the coordinates of a grid point expressed as integer values.

B.1.6 CV_SequenceRule

B.1.6.1 Introduction

The class CV_SequenceRule (Figure B.4) describes the method to be followed in assigning records from the sequence of FrameworkOrthoimage.values to grid points within the grid envelope. It has two attributes.

B.1.6.2 Attribute: type

The attribute *type* identifies the sequencing method to be used. The data type CV_SequenceType is specified in ISO 19123. The default value is "linear". Other methods for sequential enumeration are described in Annex D of ISO 19123.

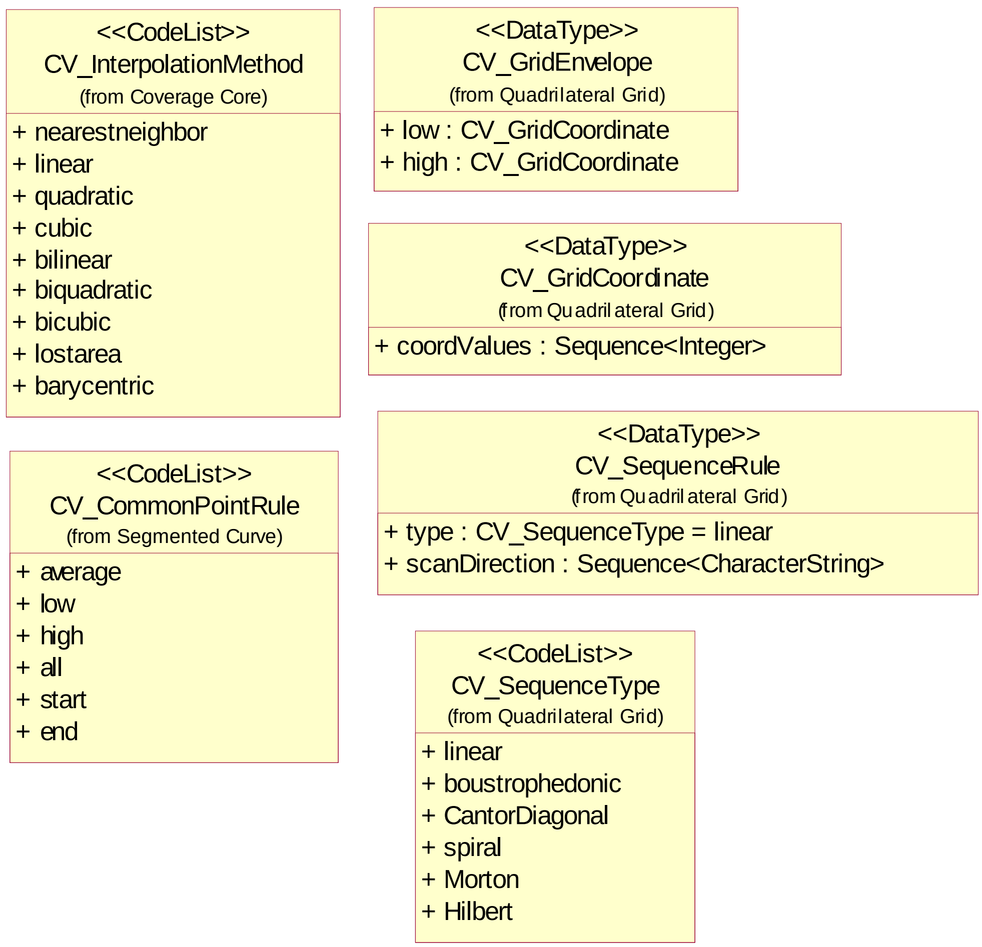

Figure B.4 – Data types from ISO 19123

B.1.6.3 Attribute: scanDirection

The attribute *scanDirection* is a sequence of signed axis names that indicates the direction in which sequencing operates. An additional element may be included in the sequence to describe interleaving of attribute values. In the case of linear scanning of a 2D grid, grid coordinates are incremented first along a grid line parallel to the first axis named in the list, and then along the second axis. To describe interleaving, the range of the coverage is treated similarly to a grid axis – the index of the list of values in a record is incremented in the same way that the grid coordinates are incremented.

EXAMPLE 1 In Figure B.5, the grid axes are named Row (R) and Column (C). The grid origin is at the upper left corner, and the axes are positive downward and to the right.

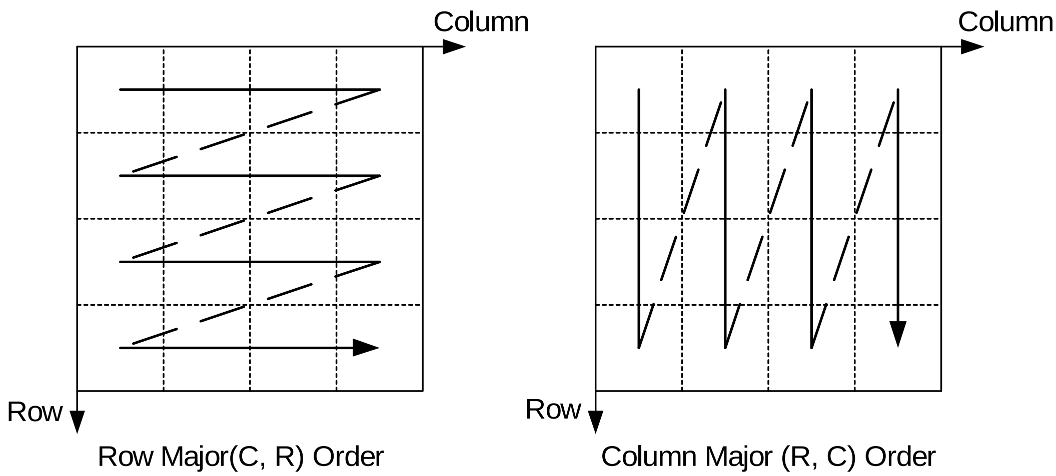

Figure B.5 – Examples of scan directions

EXAMPLE 2 Given grid axes named Row (R) and Column (C), and identifying the range of the grid coverage as A, the various forms of interleaving are identified by ordering the axes as shown in the table below.

Table B.1 – Examples of interleaving

Organization	Axis Sequence
Band interleaved by pixel	ACR or ARC
Band interleaved by row	CAR
Band interleaved by column	RAC
Band sequential	CRA or RCA

B.1.7 DirectPosition

The data type DirectPosition (Figure B.6) is specified in ISO 19107. DirectPosition has two attributes that carry the coordinates of a position and the coordinate dimension. It also has an optional association to the class SC_CRS specified in ISO 19111.

B.1.7.1 Attribute: coordinate

The attribute *coordinate* carries the coordinates of a single position as a sequence of numbers.

B.1.7.2 Attribute: dimension

The attribute *dimension* identifies the dimension of the coordinate space. This information is derived through the association to SC_CRS. For framework orthoimagery, the value of dimension is constrained to 2.

{origin.dimension = 2}

B.1.7.3 Association role: coordinateReferenceSystem

The association role *coordinateReferenceSystem* identifies the instance of SC_CRS to which the DirectPosition is referenced.

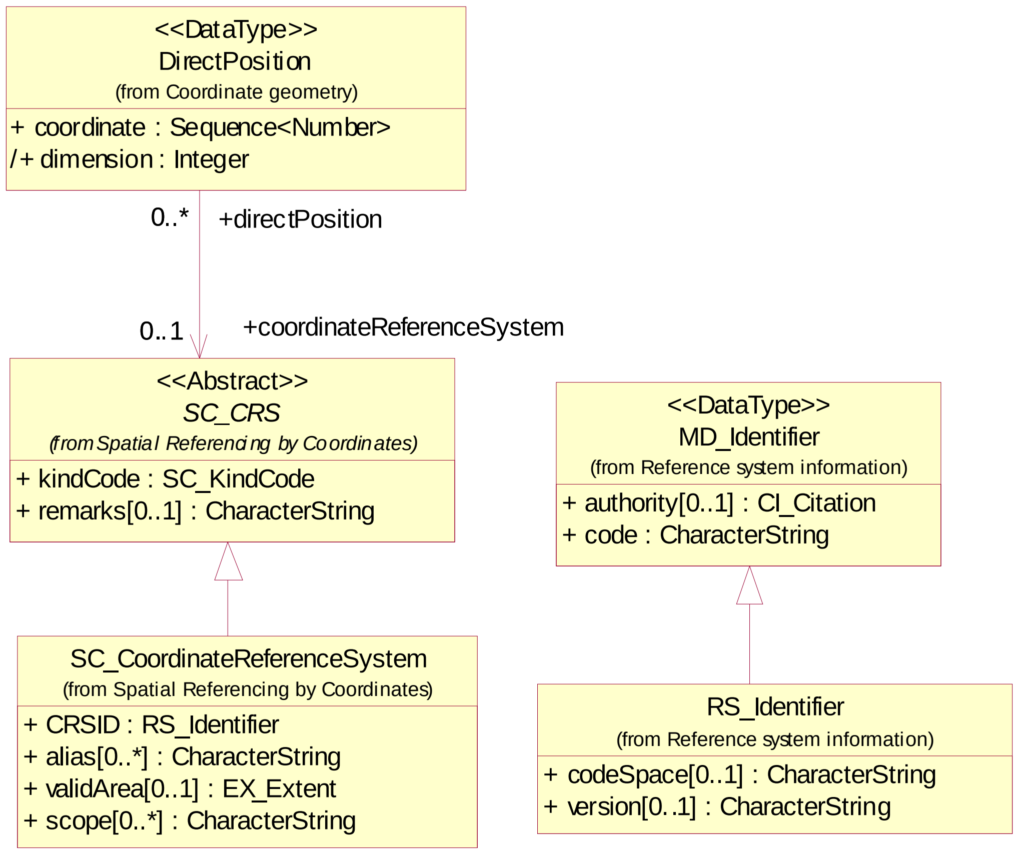

Figure B.6 – Context diagram: DirectPosition

B.1.8 SC_CRS

SC_CRS, as specified in ISO 19111 is an abstract class, meaning that it can only be instantiated as an instance of one of its concrete subclasses. This part requires that coordinate reference system be associated with either the North American Datum of 1983 (NAD83) or the datum defined for the World Geodetic System of 1984 (WGS84). These two coordinate reference systems are instances of the subclass SC_CoordinateReferenceSystem.

B.1.9 SC_CoordinateReferenceSystem

B.1.9.1 Introduction

SC_CoordinateReferenceSystem inherits two attributes from SC_CRS and has four attributes defined for the class itself. Four of these attributes are optional; none of the four is required by this part, so they are not documented in this part.

B.1.9.2 Attribute: kindCode

The attribute *kindCode* is inherited from SC_CRS. Its data type is the code list SC_KindCode, which includes two values. The value for any 2D horizontal coordinate reference system is 1, generalCase.

B.1.9.3 Attribute: CRSID

The attribute *CRSID* contains an identifier for the coordinate reference system. Its data type is RS_Identifier. RS_Identifier has one mandatory attribute, code; its value is of data type CharacterString.

B.1.9.4 Vector

The data type class Vector is specified in ISO/TS 19103. It has two attributes.

B.1.9.5 Attribute: dimension

The attribute *dimension* indicates the dimension of the coordinate reference system, which is constrained to 2 in the case of this part.

B.1.9.6 Attribute: ordinates

The attribute *ordinates* provides the ordinates relative to each axis of the coordinate reference system.

B.1.10 RecordType

The class RecordType is specified in ISO/TS19103. It is best described as a sequence of name:value pairs each described by an instance of the class MemberName.

B.1.11 MemberName

B.1.11.1 Attribute: aName

The attribute *aName* is the name of the attribute expressed as a CharacterString.

B.1.11.2 Attribute: attributeType

The attribute *attributeType* is the name of the data type of the attribute, expressed as a CharacterString.

Annex C
(normative)
Orthoimagery data dictionary

Table C.1 – Orthoimagery data dictionary

Line	Name/Role Name	Definition	Obligation/ Condition	Maximum Occurrence	Data Type	Domain
1	FrameworkOrthoimage					Lines 2-16
2	domainExtent	Spatial extent of the image	M	*	<<DataType>> EX_Extent	Defined in ISO 19115
3	rangeType	Description of the types of values in the range of the coverage	M	1	RecordType	Unrestricted
4	interpolationType	Recommended method for interpolating values at points within grid cells	M	1	<<CodeList>> CV_InterpolationType	Defined in ISO 19123
5	commonPointRule	Rule to follow in interpolating a value at a point that falls on the boundary between two pixels	M	1	<<CodeList>> CV_CommonPointRule	Defined in ISO 19123
6	dimension	Dimension of the image grid	M	1	Integer	2
7	origin	Coordinates, in an external coordinate system, that map to grid coordinates 0, 0	M	1	<<DataType>> DirectPosition	Defined in ISO 19107
8	axisNames	Names of the axes of the image grid	M	1	Sequence<CharacterString>	“row”, “column”
9	offsetVectors	Vectors that specify the orientation of the grid axes and the dimensions of the pixels in directions parallel to the axes	M	1	Sequence<Vector>	Unrestricted
10	extent	Limits of the set of pixels included in the image	M	1	<<DataType>> CV_GridEnvelope	Defined in ISO 19123

Line	Name/Role Name	Definition	Obligation/ Condition	Maximum Occurrence	Data Type	Domain
11	sequencingRule	Rule for assigning values to specific pixels	M	1	<<DataType>> CV_SequenceRule	Defined in ISO 19123
12	startSequence	Grid point associated with the first record in the values sequence	M	1	<<DataType>> CV_GridCoordinate	Defined in ISO 191123
13	values	Recorded radiance values	M	1	Sequence<Record>	Unrestricted
14	metadata	Data about the FrameworkOrthoimage	O	1	<<DataType>> Framework:: ExternalResource	Unrestricted
15	Role name: component	FrameworkOrthoimage that is part of a mosaic	C/Is image part of a mosaic?	*	Orthoimage	Unrestricted
16	Role name: mosaic	Orthoimage composed of smaller Orthoimages	C/Is image composed of parts?	1	Orthoimage	Unrestricted
17	OrthoimageryCollection	FrameworkOrthoimages exchanged as a set				Lines 18-19
18	metadata	Data about the OrthoimageryCollection	O	1	<<DataType>> Framework:: ExternalResource	Unrestricted
19	Role name: member	Pointer to a FrameworkOrthoimage included in the OrthoimageryCollection	M	*	Orthoimage	Unrestricted
20	CV_GridEnvelope	Grid coordinates for the diametrically opposed corners of the image				Lines 21-22
21	low	Minimal grid coordinate values of the image	M	1	<<DataType>> CV_GridCoordinate	Defined in ISO 19123
22	high	Maximal grid coordinate values of the image	M	1	<<DataType>> CV_GridCoordinate	Defined in ISO 19123
23	CV_GridCoordinate	Data type for holding the				Line 24

Line	Name/Role Name	Definition	Obligation/ Condition	Maximum Occurrence	Data Type	Domain
		coordinates of a grid point				
24	coordValues	Number of pixel offsets from the origin of the grid parallel to each axis	M	1	Sequence<Integer>	Positive
25	CV_SequenceRule	Description of how grid points are ordered for association to the elements of the sequence values				Lines 26-27
26	type	Identifier of the type of sequencing method	M	1	<<DataType>> CV_SequenceType	Defined in ISO 19123
27	scanDirection	List of signed axisNames that indicates the order in which grid points shall be mapped to position within the sequence of values	M	1	Sequence<CharacterString>	Unrestricted
28	DirectPosition					Lines 29-31
29	coordinate	Numerical description of the spatial position	M	1	Sequence<Number>	Unrestricted
30	dimension	Dimension of the coordinate space	M	1	Integer	2
31	Role name: coordinateReferenceSystem	Spatial reference system to which the positions is associated	M	1	<<Abstract>> SC_CRS	Defined in ISO 19111
32	SC_CoordinateReferenceSystem					Lines 33-34
33	kindCode	Type of coordinate reference system	M	1	<<Enumeration>> SC_KindCode	Defined in ISO 191111
34	CRSID	Name of the coordinate reference system	M	1	<<DataType>> RS_Identifier	Defined in ISO 19111
35	RS_Identifier				<<DataType>>	Lines 36
36	code	Code that identifies the coordinate reference system	M	1	CharacterString	Unrestricted

Line	Name/Role Name	Definition	Obligation/ Condition	Maximum Occurrence	Data Type	Domain
37	Vector					Lines 38-39
38	dimension		M	1	Integer	2
39	ordinates		M	2	Number	Unrestricted
40	RecordType				<<Metaclass>>	Line 41
41	qualifier: attributeMember	Name and data type of the attribute	M	*	MemberName	Unrestricted
42	MemberName					Lines 43-44
43	aName	Name of the attribute	M	*	CharacterString	Unrestricted
44	attributeType	Data type of the attribute	M	*	CharacterString	“Integer”

Annex D
(informative)
Data example

The data below represent an orthoimagery coverage that holds reflectances for three bands of the visible spectrum interleaved by pixel in row major sequence. The grid is referenced to NAD83 with a grid spacing of 1 arc second. The image covers an area 2 minutes in latitude by 5 minutes in longitude.

Table D.1 – Data example

Line	Name/Role Name	Value		
1	Orthoimagery Coverage			
2	domainExtent[1]	westBoundLongitude	76.00000	
		southBoundLatitude	39.46667	
		eastBoundLongitude	75.91667	
		northBoundLatitude	39.50000	
3	rangeType	aName:attributeType		
		red:Integer		
		green:Integer		
		blue:Integer		
4	interpolationType	bilinear		
5	interpolationParametersType	------		
6	commonPointRule	average		
7	role name: data	see row 8		
8	FrameworkOrthoimage			
9	dimension	2		
10	axisNames	row, column		
11	origin	coordinate	39.500, 76.000	
		dimension	2	
		coordinateReferenceSystem.kindCode	1	
		coordinateReferenceSystem.name	NAD83	
12	offsetVectors	dimension	ordinates (1)	ordinates (2)
		2	-0.00028	0
		2	0	-0.00028
13	extent	low	0,0	

Line	Name/Role Name	Value	
		high	120,3000
14	startSequence	0,0	
15	sequencingRule	type	linear
		scanDirection	column, row
16	values	239, 17, 128	
		37, 219, 50	
		etc., for a sequence of 36421 records	
17	role name: component	-------	

[1] Uses Ex_GegraphicBoundingBox, a subclass of EX_Extent.

Annex E
(informative)
Additional information about control

Currently, there are three methods used to acquire the necessary control; from existing map or digital orthoimagery, from a ground survey, or from a platform specific navigation direct georeferencing system composed of an Airborne Global Positioning System (AGPS) and Inertial Navigation System (INS).

Control data in the form of survey ground control provides coordinates and elevations of known locations on the Earth's surface which are used in the orthorectification process to obtain the precise location and orientation of the raw image at the time it was acquired. This is accomplished through a process called aerotriangulation which derives the camera attitude and positions by performing a space resection using ground control, tie points, and camera model geometry. When completed, this process provides the location and orientation information of the all the imagery allowing the user to locate any on-the-ground positions to known projections, coordinates, and accuracy standards.

Control derived from existing map or orthoimagery sources can also be used during the orthorectification process similarly to that of survey ground control. Control locations would consist of known horizontal and vertical values that, in turn, can be used in aerotriangulation process. For any given final orthoimage scale, control derived from a less accurate source is not recommended.

Direct georeferencing currently incorporates both airborne AGPS and INS data and is the measurement of sensor position and orientation allowing for direct relationship between locations on the imagery to locations on the ground, without the need for additional ground information over the project area.

Airborne GPS consists of a GPS unit on an aircraft that captures range measurements to satellites and uses triangulation techniques to compute the position of the receiver's antenna and relates that position to the sensor.

Inertial Navigation System is composed of two components, one is the inertial measurement unit (IMU) comprised of a series of accelerometers and gyros that measure position, orientation, and velocity, and the second is the navigation processor of the INS which solves for the motion of the IMU. The two combined provide a navigation solution comprised of the platform's position, velocity, and orientation.

When the data from the AGPS system is integrated with the INS data, the 3-dimensional and angular position of the aircraft sensor can be accurately estimated as the position of the AGPS complements that of the INS data providing location and orientation information helping to estimate and correct the errors of the imaging platform. The AGPS and INS data can then be used to help locate and orient the image in space during the orthorectification process.

At times, digital orthoimagery may be created using direct georeferencing information without the need of any ground survey control. In other cases, this information is used to augment the aerotriangulation block adjustment solution.

Annex F
(informative)
Bibliography

The following documents contain provisions that are relevant to this part of the Framework Data Content Standard. Annex D of the Base Document (Part 0) lists informative references applicable to two or more of the parts of the standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

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